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Using Financial Futures in Trading and Risk Management

Ignacio Mas
Jesús Saá-Requejo

Financial futures have become the cornerstone of financial management. The paper explains the contractual features of an array of financial futures, basic pricing relationships, and how futures can be used by investors and risk managers.

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Summary findings

Mas and Saá-Requejo explain the features of an array of futures contracts and their basic pricing relationships and describe a few applications to show how investors and risk managers can use these contracts.

Futures — and derivatives generally — allow economic agents to fine-tune the structure of their assets and liabilities to suit their risk preferences and market expectations. Futures are not a financing or investment vehicle per se, but a tool for transferring price risks associated with fluctuations in asset values. Some may use them to spread risk, others to take on risk.

Financial futures (along with options) are best viewed as building blocks. Futures have facilitated the modern trend of separating conventional financial products into their basic components. They allow not only the reduction or transformation of investment risk but also the understanding and measurement of risk.

The market for derivatives has grown enormously over the past decade. The value of exchange-traded eurodollar derivatives (futures and options) is equal to roughly 13 times the value of the underlying market. The volume of trading in financial futures now dwarfs the volume in traditional agricultural contracts.

As emerging markets develop, given their inherently risky nature, expect financial futures to play a prominent role in risk management.

This paper — a product of the Private Provision of Public Services Unit, Private Sector Development Department — is part of a larger effort in the department to promote risk management techniques in emerging markets. Copies of the paper are available free from the World Bank, 1818 H Street NW, Washington, DC 20433. Please contact Kay Binkley, room E-1243, extension 81143 (51 pages). March 1995.

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Ignacio Mas
World Bank

and

Jesús Saá-Requejo
University of Chicago

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I. Financial Futures Market Overview

A. Basic futures contract design

Definition. A futures contract is a *commitment* to buy or sell a *fixed amount* of a *standardized* commodity or financial instrument at a *specified time* in the future at a *specified price* established on the day the contract is initiated and according to the rules of the regulated exchange where the transaction occurred. Once the trade clears, the buyer and corresponding seller of the futures contract are not exposed to each other's credit risk. Rather, they individually look to the clearinghouse for performance, and vice versa. This performance risk is held very low by daily marking-to-market of positions through a margining system.

Futures as a derivative security. A futures contract is a financial derivative of the commodity on which it is based in the sense that it is an arrangement for exchanging money on the basis of the change in the price or yield of some *underlying* commodity.

Timing of cash and commodity flows. Like other derivative securities, a futures contract is an agreement to do something in the future -- no goods or assets are exchanged today. A *cash market* transaction involves an agreement between two counterparties to buy or sell a commodity for cash today (perhaps for delivery in a couple of days). In a *forward market* transaction, delivery and settlement of the commodity for cash will occur at a *single* future date with no intervening cash flows. In a *futures market* transaction, delivery and settlement will also occur at a single future date but there will be daily (or more frequent) cash flows reflecting intervening price movements in the underlying commodity.

Value of futures contracts at the time of contracting. Since there is no exchange of commodities nor cash payments at the time of contracting of futures contracts, such contracts must have a zero net present value at their inception. There is no mechanism for offsetting positive or negative value at the time of contracting, and hence they must be priced so that the pre-specified exchange of the commodity for cash at the time of settlement has zero net value as of the time of contracting.

Value of futures contract as spot price changes. Once the futures contract is entered into, subsequent movements in the (spot) market price of the commodity create value for either the long futures position (i.e., the buyer) or the short futures position (i.e., the seller). For instance, a rise in the spot price of the commodity will benefit the long as he has bought the commodity under the futures contract at a fixed price and can now expect to sell it in the future at a higher price in the spot market. But since the long will not realize this gain until the settlement of the futures contract, this creates a credit exposure to the extent of the net present value of the futures contract. The futures contract will now be a positive net present value investment for the long and an obligation for the short.

Margining. A daily (or more frequent) margining system is designed to mitigate this credit exposure by requiring daily net payment equal to the net present value of the futures contract. Thus, if on a certain day the price of the underlying commodity rose, investors short the futures contract (i.e., those who sold it) will pay the exchange while investors long the futures contract (i.e., those who bought it) will receive payment from the exchange. It is as if at the end of the day the previous forward purchase or sale contract was torn and a new, readjusted one was established automatically.

Types of margin requirements. In actuality, there are two types of performance bonds. *Initial margin* is required before a customer can enter into a futures contract. This is a good-faith deposit or performance bond rather than a down-payment on a futures contract. *Variation margin* is the gain or loss attributable to the futures position based on the mark-to-market process. Both are required in order to minimize counterparty default risk under the futures contracts.

Closing a futures position. A futures position can be closed out before expiration of the contract by entering into an offsetting trade in the same contract for the same amount. Alternatively, a contract can be held until expiration. Each contract can provide for either *physical delivery* or *cash settlement* at expiration. Under physical delivery, investors that are long the contract must deliver to investors short the contract the underlying commodity of the contract according to the rules on commodity quality and timing established by the exchange. The matching of longs and shorts is done at random by the exchange. Under cash settlement, no physical exchange of the underlying commodity takes place. Rather, the contract is settled in cash in an amount computed to be equal to the value of the underlying commodity that would otherwise be delivered. The determination of the price of the commodity at expiration on which cash settlement amounts are calculated (the *final settlement price)* is made by the exchange under pre-specified rules.

Types of underlying instruments. Underlying every futures contract is a relatively active cash market for an asset or good. Futures contracts were traditionally based on standard *physical* commodities such as grains (corn, wheat, soybeans), livestock (live cattle and hogs), energy products (crude oil, heating oil) or metals (aluminum, copper, gold), softs (coffee, sugar, cocoa). In addition, there are futures on several commodity indices (like the CRB and GSCI). Over the last two decades, futures based on *financial* commodities have flourished, such as those based on:

- Money market interest rates: certificates of deposit, offshore or euro-deposits (e.g., LIBOR-based), and Treasury bills.
- Bonds and notes: Treasury securities.
- Currencies: yen, deutschemark, pound (against the dollar or crosses)
- Equity indices: S&P500, Nikkei 225, NYSE Composite.

Some of these financial futures contracts will be discussed at length below. Chapter II will present short-term interest rate futures, especially futures on international bank ("euro") deposits. Chapter III will present Treasury note and bond futures. Futures on currencies and equity indices will be treated in Chapters IV and V, respectively.

B. Forward vs. futures contracts

Overview. Futures and forward contracts are similar in the sense that they both establish a price and a transaction to occur in the future. However, there are several significant differences stemming from the differences in cash flows alluded to earlier.

Cash flows and margining. As discussed above, in forward markets cash changes hands only on the forward date. The credit risk embedded in forward contracts depends on price movements spanning the duration of the forward contract. In futures markets, gains and losses are settled daily in the form of margin payments. This serves to reduce credit exposure to intra-day price movements. The drawback of such frequent marking-to-market of futures contracts is the unpredictability of cash flows and the transactions costs involved with maintaining adequate margin accounts.

Tradability. The relatively high potential credit exposure of forward contracts makes them less easily tradable since the value of the forward contract is dependent on the identity of the counterparty (the nature of the potential credit risk involved). In other words, forward contracts will trade on the basis of price *and* credit characteristics of the counterparty. For this reason, forward contracts tend to be traded in *over-the-counter* (OTC) markets, so that implicit credit charges can be factored into pricing in a discretionary. negotiated basis. In contrast, margin requirements on futures contracts make them sufficiently immune to credit risk so that credit exposure is not a significant factor in pricing. This makes futures contracts particularly well-suited for trading in organized exchanges.

Pricing and fees. An implication of these different trading schemes is that the prices of OTC forwards are often not publicly observed whereas the prices of exchange-traded futures are continuously disseminated. Commission fees on exchange-traded futures are explicit and are negotiated based on the volume of transactions. With OTC forwards, fees are explicit and/or implicit in the bid-ask spread.

Contract terms. Organized exchanges are a particularly efficient trading system in deep, liquid markets. To ensure the liquidity of exchange-traded futures markets, contracts tend to be offered on standardized terms in terms of maturity, contract size, quantity and quality of the underlying to be delivered, the time and place of delivery, the method of payment, margining requirements and trading hours, among other characteristics. In this fashion, negotiation at the floor of the exchange can take place in only one dimension: price. This facilitates quick and efficient exchange and reduces the risk of errors and mis-communications at the time of negotiation. In contrast, OTC markets are less dependent on trading volume to ensure liquidity as long as there is a sufficient number of market makers. Accordingly, since there is less of a premium on quick negotiations, OTC forwards tend to have settlement dates and maturities that better suit the trading partners. In particular, forwards can carry any maturity while futures are restricted to exchange-established maturity dates. Exchange-traded futures contracts will also contain price thresholds and maximum daily price movements which do not exist in the case of forward contracts.

Credit exposure. In futures contracts, the clearing house members and the clearing-house itself guarantee fulfillment of futures contracts. The buyer and the seller both have an exposure to the clearing house (and the clearing house to them), rather than to each other. Thus, with futures, potential credit exposure is not only lower due to margining but also more diversified as it arises with the pool of clearing house members rather than with individual counterparties.

Offsets of longs and shorts. Because of the standardization of futures contracts and the intermediation of credit exposure through the clearing house, contracts of the same underlying commodity and maturity are fully fungible. This permits offsetting of long and short positions (purchases and sales) in the same contract month. In forward markets, purchases and sales, even with the same trading partner, remain in the books as open long and short positions. Forward contracts can only be closed out by negotiating with the *same* counterparty or by assignment of the contract to a new counterparty, both of which may be time-consuming, expensive or not forthcoming. In practice, forwards are most easily reversed by entering into a new opposite forward which offsets the original contract (in a financial, but not accounting, sense). For these reasons, use of forwards can result in the bloating of the balance sheet.

Regulation. Since forwards are a bilaterally negotiated agreement, there is no formal regulation of forwards nor is there a body to handle customer complaints. Exchange-traded futures, on the other hand, are regulated by identifiable entities which are either governmental (like the Commodity Futures Trading Commission in the U.S.) or set up by the industry itself.

C. Financial futures: Uses and users

Uses. Financial futures can be used as devices for: (i) arbitrage or yield enhancement, (ii) risk management and hedging, and (iii) taking trading positions on the basis of market views (or "speculating," to put it in more blunt terms). The advantage of futures over cash instruments for these purposes are threefold: their off-balance sheet nature, their high leverage (requiring low cash payments), Each type of futures presented in Chapters II-V will be analyzed according to each of these three applications. As a preview, here we discuss the basic approaches for each.

Arbitrage. Pure (i.e., riskless) arbitrage entails the exploitation of theoretical pricing relationships. The prices of futures are related to those of the underlying commodity on which they are based; temporary violation of these relationships might give rise to "cash-futures" arbitrage. Sometimes the prices of futures can be related as well to those of other derivatives which are based on the same (or similar) underlying commodities. Examples of related derivatives are interest rate swaps and interest rate futures, and futures on three-month LIBOR and on one-month LIBOR. By isolating each characteristic of some underlying security with a derivative instrument, all arbitrage risk can be eliminated.

Risk management. Hedging can be performed on a single transaction (or instrument) basis or on an aggregate (portfolio or firm) basis. Examples of single transaction hedging might include anticipatory hedging for debt or equity security issuance or currency hedging for foreign trade transactions. Examples of aggregate firm hedging include asset-liability gap management and portfolio duration management. Financial futures are particularly apt for managing foreign currency and interest rate risk.

Expressing market views. Financial futures are an efficient way of taking bets on the market on the basis of traders' views, whether these are fundamental (i.e., driven by economic conditions and trends) or technical (i.e., based on observed short-term price movements). Such trades by definition cannot (indeed, should not) be fully hedged, although trade construction might be such as to immunize particular kinds (or dimensions) of risk. Unlike pure arbitrage, expressing market views is not riskless. Futures can be used to express views on general market *direction*, the *timing* of expected market movements, changes in the *spread* between market segments (e.g., credit, commodity quality or cross-country differences), or a combination of these.

Users. The users of financial futures are naturally given by their uses. Financial institutions, including commercial banks, brokerage firms, investment banks, fund managers and insurance companies will use futures for their three basic functions. Non-financial corporations, including municipal and state organizations and foundations are more likely to use them to hedge their commercial, investment or borrowing activities. Individuals and locals are more likely to use them for speculation and arbitrage.

D. Futures exchanges: Structure, operations and control

Customer involvement. A customer wishing to initiate a futures trade (whether opening or closing a futures position) will chose a Futures Commission Merchant (FCM) through which it will trade. The customer directs all trading decisions, and the FCM will execute it by acting as an intermediary with the exchange. The customer pays (collects) margin to (from) the FCM on a daily or otherwise negotiated basis, and will arrange for settlement of all open positions.

Functions of the FCM. As a clearing house member, the FCMs (but not their customers) have trading privileges and floor access at the exchange. The basic function of the FCM is to provide facilities for trade execution and clearing services to its customers. In this connection, the FCM will calculate required initial margin for customers and collect any margin deficiencies from customers on a daily (or otherwise negotiated) basis. Because the FCM guarantees its customer's trades in the first instance, it will set minimum financial guidelines for its customers. On the customer's behalf, the FCM will oversee deliveries, exercises (for options) and assignments. As a service, it will also send daily statements to customers and monitor customer positions. In addition, the FCM might generate and provide trade ideas for customers.

Functions of the clearing house. The basic function of the clearing house is to provide clearing and settlement services to its members. It also oversees the settlement of all open futures contracts by offset, physical delivery, cash settlement or exercise (in the case of options). Because the clearing house and its members collectively guarantee fulfillment of futures contracts, it will protect itself by: (i) performing surveillance of and setting minimum financial resource requirements for its clearing members; (ii) running the margining system, and in particular calculating required initial margin, paying/collecting daily variation margin calls and holding margin deposits for each member; and (iii) monitoring the entire safeguard system. Clearing members contribute financial backing to the financial safeguard system and are subject to periodic audits (by the DSRO in the U.S.).

Membership in the clearing house. Individual membership in the exchange may include independent traders who provide their own capital ("locals"); representatives of brokerage firms, commercial banks and investment banks; and representatives of FCMs. In each of the Chicago exchanges, for instance, there may be several thousand individual clearing house members. In addition, there may be clearing members which are corporations, partnerships and proprietorships that satisfy the membership requirements of the specific clearinghouse.

World futures exchanges. Exchanges are formal organizations whose purpose is to concentrate order flow in order to facilitate competition and to reduce transaction costs involved in searching for counterparties. The principal financial futures exchanges in the world are:

Chicago Mercantile Exchange (CME, or the "Merc")
Chicago Board of Trade (CBOT)
Tokyo International Financial Futures Exchange (TIFFE)
Tokyo Stock Exchange (TSE)
London International Financial Futures and Options Exchange (LIFFE)
Marché à Terme International de France (MATIF) in Paris
Singapore International Monetary Exchange (SIMEX)
Deutsche Terminbörse (DTB) in Frankfurt
New York Futures Exchange (NYFE)
Mercado Español de Futuros y Opciones Financieras (MEFF) in Barcelona

GLOBEX. GLOBEX is an electronic trading system originally developed by the CME and the CBOT. Other exchanges such as MATIF participate in the system. GLOBEX offers a trading outlet for market participants who wish to place orders outside regular trading hours (when the trading floor is closed).

Trade execution under open outcry. The majority of futures exchanges still operate under the open outcry method in traditional circular *pits*. All trades are initiated by the customer and are relayed to the floor broker at the exchange. The customer may phone the floor broker directly, or may call an off-site broker which in turn relays the trade to the floor broker. The floor broker messengers or hand signals the trade to the pit broker. The pit broker executes the trade via open outcry (agreeing on contract, amount and price). The pit broker messengers or hand signals the trade information back to the floor broker. The broker then confirms the trade with the customer.

Trade execution under automated systems. In some exchanges, buyers and sellers submit quotes to a centralized computer system which automatically matches trades according to time and price priority rules. If operating through a broker, an end-user need not observe any differences between the two trading methods.

Setting margin requirements. The minimum initial margin is set by the exchange, but individual FCMs may request additional initial margin. Variation margin between the FCM and the exchange is set by the exchange, and settlement is performed at least daily. Different arrangements may be made between the customer and the FCM in terms of the amount of the margin and the frequency of settlements. Most major exchanges and clearing organizations have adopted SPAN, a risk-based margining system that calculates margin on a portfolio rather than on an individual contract basis.

Forms of margin deposits. Acceptable forms of margin deposit at the clearing houses are determined by each exchange and typically include cash, Treasury securities and letters of credit. Acceptable forms of margin deposit at the clearing firm or FCM may include listed securities in addition to the above.

Risk management and control. Clearing houses are very sensitive to risk-taking by member firms as the clearing house becomes buyer to every selling clearing member and seller to every buying clearing member. Each exchange has a team of audit, surveillance and clearing staff who monitor the impact of market moves on clearing firms continuously. Clearing houses actively monitor the financial condition and operational condition of clearing firms. Clearing houses also monitor the financial integrity of securities deposited as margin, including the *haircut* for Treasury securities and the financial stability of approved banks issuing letters of credit. Clearing houses have the right to call for settlement whenever market conditions warrant such a call. Most clearing houses require clearing members to maintain a security deposit in addition to margin deposits.

II. Short-Term Interest Rate Futures

A. Contract specifications

An assortment of contracts. The eurodollar contract is the linchpin of the short-end interest rate futures contracts. Because of its unflagging market significance, the eurodollar contract is described at length below. It is used here as a prototype to define standard futures contract terms. Then we review similar non-dollar-denominated inter-national bank ("euro") deposit contracts. Finally, we introduce other dollar-denominated short-term interest rate futures; no comparable contracts exist for other currencies.

(a) Eurodollar futures

Overview. The eurodollar futures market is the most widely traded money market contract in the world, although trading in it only started as recently as 1981. It is based on a ninety-day eurodollar deposit, which is a dollar-denominated deposit with a bank or branch outside of the U.S. or with an international banking facility (IBF) located in the U.S. Eurodollar deposits differ from domestic term deposits or certificates of deposit in the U.S. in that they are not regulated by U.S. authorities, and hence are not subject to reserve requirements or deposit insurance premiums. The eurodollar futures rate on any particular contract-month is essentially the 3-month LIBOR rate that is expected to prevail at the maturity of the contract.

Basic contract specifications. The nominal *contract size* is $1 million and the underlying rate is the three-month LIBOR, the rate at which a London bank is willing to lend dollars (i.e., the offer side of the cash money market). The *futures price* is quoted as 100 minus the annualized futures 3-month LIBOR (e.g., a price of 96.5 implies a futures LIBOR rate of 3.5% per annum) in decimal terms. The basic *tick size* (the smallest decimal denomination of the price and the minimum price change) is .01, which is equivalent to one basis point in the underlying LIBOR rate. There are four contracts per year (expiring on the third Wednesday of every March, June, September and December), and there are contracts out to seven years (at the CME) -- for a total of 28 concurrent contracts.

Contract settlement. Eurodollar contracts are settled in cash rather than with physical delivery (which would entail the short opening a time deposit on behalf of the long). The disadvantages of delivery in this case are of two kinds: (i) eurodollar deposits are non-negotiable and hence delivery would bind the long to a three-month investment; (ii) heterogeneity of bank credits would systematically raise questions on the quality of the delivered asset. The final settlement price used to close out all open positions upon expiration of the contract is determined by the exchange on the last trading day based on a poll of banks in London to determine spot LIBOR. Thus, the underlying is an average of rates quoted by banks. The sampling and polling procedure followed by the exchange to determine the final settlement price is designed to avoid all possibility of manipulation of the LIBOR rate prevailing on that date (e.g., by rejecting the two highest and lowest LIBOR quotes).

Computing gains and losses. The *dollar value of a tick* (or basis point change in the underlying LIBOR) for the eurodollar contract is \$25. This amount is given by the dollar gain or loss from a basis-point change on a ninety-day deposit (i.e., notional principal amount times the day-count factor according to the money-market convention times a basis point, or \$1,000,000 × 90/360 × .0001 = \$25). Accordingly, the daily gain (loss) from a long eurodollar position is equal to \$25 times the basis-point decrease (increase) in the underlying LIBOR rate in that day (or against the final exchange-determined settlement rate upon expiration) times the number of contracts held. Conversely, the daily gain (loss) for the short is equal to \$25 times the basis-point increase (decrease) in the LIBOR rate. This profit/loss gives rise to variation margin.

Trading of eurodollar contracts. Eurodollar contracts are now traded at the CME in Chicago, at LIFFE in London and at SIMEX in Singapore. Thus, eurodollar contract trading is *de-facto* available 24 hours. The eurodollar contracts on CME and SIMEX are identical (except for trading hours), and are in fact completely interchangeable and can be mutually offset. The eurodollar contract on LIFFE, on the other hand, settles at a different time of day and uses a slightly different polling sample and procedure to determine the settlement price, and hence is not exactly identical to (though it is certainly a close substitute of) the other two.

(b) Other money market futures contracts

Non-dollar international bank deposit futures. Contracts on three-month bank deposits exist for most major currencies at one or more exchanges, including the yen, deutschemark, pound sterling, French franc, Swiss franc and Italian lira. These contracts have very similar characteristics to the eurodollar contract as specified above, except for the notional principal value (and, correspondingly, the tick value) which is denominated in each currency and may or may not be equal to one million. The underlying rate may be that of a euro (i.e., offshore) deposit or of a domestic deposit (as is the case with the British "short sterling" and French PIBOR contracts). Note that day count conventions on money markets may change (either actual/360 or actual/365), and so the formulae given below for eurodollars might need to be changed accordingly in other market.

International contracts and exchanges. The table below summarizes the main terms of 3-month international bank deposit contracts detailing where they are traded:

Name of Contract	Currency	Exchange(s) Where Traded	Principal Amount	Tick Value
Eurodollar	USD	CME, LIFFE, SIMEX	1,000,000	25
Short Sterling	GBP	LIFFE	500,000	12.5
EuroMark	DEM	LIFFE, DTB, SIMEX, MATIF	1,000,000	25
EuroYen	JPY	TIFFE, SIMEX	100,000,000	2,500
Pibor	FRF	MATIF	5,000,000	125

Other dollar-denominated bank deposit futures. There are two other short-term interest rate futures based on bank deposit rates in dollars:

- A *one-month eurodollar* contract traded on the CME, in which the underlying rate is the one-month rather than the three-month LIBOR eurodeposit rate. Note that the one-month LIBOR and the 3-month LIBOR contracts have been designed to have the same tick value of $25; thus, the contract size of the one-month LIBOR (at $3 million) is three times that of the eurodollar contract.

- A *30-day fed funds* contract traded on the CBOT, in which the underlying rate is a 30-day average of the overnight fed funds rate offered by U.S. banks. The underlying, an inter-bank rate, corresponds to a domestic rather than a eurodollar deposit. An interesting feature of this contract is that the futures settlement rate is determined in the course of the last trading month and not on the last trading date. This is because the underlying is the average fed funds rate *during the last month of trading* of the contract.

Like the eurodollar contract, these are cash settled. Contracts are available for every month in the front year but do not extend over a year.

Non-bank deposit U.S. money market futures. In addition, there is a *91-day U.S. Treasury bill* contract traded on the CME, which is actually the precursor of all money market futures since its inception dates back to 1975. Unlike the previous ones, this contract requires delivery of a particular (unique) Treasury bill upon expiration rather than cash settlement. In this case, physical delivery presents few problems since the T-bill market in the U.S. is sufficiently deep to preclude the possibility of manipulation of the underlying instrument at the time of settlement of the contract. There are no corresponding bill futures outside the U.S.

B. Pricing and arbitrage: Implied forward rates

Overview. In order to understand how futures prices are established, we need to understand how prices of futures contracts are related to the spot or cash market prices of the underlying asset. We will see that the market forces of arbitrage are used to price virtually all financial futures contracts. All examples drawn below are based on the three-month eurodollar contract; applications with contracts based on different currencies, maturities or underlying asset constitute a straight-forward extension. The methodology developed in this section applies only to cash-settled futures. (Arbitrage of bill futures against their deliverable securities is analogous to the basis trading expounded in the next chapter, with the simplification of having only one bill in the delivery basket of each bill contract.)

Futures and implied forwards: a first approximation. Because a eurodollar futures contract settles in cash to a final settlement price equal to 100 minus the value of the spot 3-month LIBOR at expiration, eurodollar futures ought to behave much like 3-month forward deposits. The value of forward interest rates is in turn implicit in the spot yield curve. Hence, futures prices can be derived from observable spot rates.

Calculating implied forwards: an example. To see how one can derive implied forward rates from the spot yield curve, consider an example. If we have a 5-month investment horizon, we can either: (i) invest in a 2-month eurodollar deposit (at the known 2-month spot interest rate of, say, 4%) and roll it over upon maturity into a 3-month deposit, or (ii) invest in a deposit spanning the entire investment horizon of 5 months (at the known 5-month spot interest rate of, say, 4.5%). At the moment we do not know what the rate on the second (forward) deposit under option (i) will be -- call it r_f. We can, however, determine what r_f should be in order that the return per dollar of principal on the two investment strategies --which we consider a priori to be analogous--- be identical.

Total return on strategy (i) = $[1 + 4\% \times (60/360 \text{ days})]\text{x}[1 + r_f\% \times (90/360 \text{ days})]$
Total return on strategy (ii) = $[1 + 4.5\% \times (150/360 \text{ days})]$

Equating these two expressions and solving for r_f, the implied forward rate, we find that the forward deposit must return 4.80% for the investor to be indifferent between the two strategies.

<u>Cash-forward arbitrage relationship</u>. Any term deposit can be broken down into any number of components: a shorter term deposit and one or more forward deposits. We have illustrated this in the above example by using the following relationship:

(long 2-mo. spot deposit) + (long 3-mo. forward deposit) = (long 5-mo. spot deposit)

from which one can see directly that:

(long 3-mo. forward deposit) = (long 5-mo. spot deposit) + (*short* 2-mo. spot deposit)

This suggests the construction of an arbitrage trade that could be used to exploit any divergence of r_f from its theoretical value of 4.80%. If $r_f > 4.80\%$, it pays to invest in the forward deposit (lend forward) rather than investing in a 5-month deposit (i.e., lending spot) and shorting a 2-month deposit (i.e., borrowing spot). One could actually make money if this situation arose by going long the forward deposit and short the *synthetic* forward (i.e., shorting the 5-month spot deposit and going long the 2-month spot deposit). As the forward rate is bid down in the process due to higher investor interest in the instrument, the two sides of the equation will tend to equalize. Thus, arbitrage will drive the forward rate towards the implied or theoretical rate (within the bid-ask spread). The reverse argument applies if $r_f < 4.80\%$.

<u>Cash-futures arbitrage</u>. The forward rate implied by a eurodollar futures contract is given by 100 minus its price. Thus, in the above example, a "fairly" priced future on 3-month LIBOR expiring two months from now would be one selling for 100-4.80=95.20. If the price of the futures is trading lower than this, say at 95.20 (implying a forward LIBOR rate of 4.80%), one could arbitrage this by doing the following trade (with a notional size arbitrarily set at $1 million):

- *Borrow* (short deposit) $1 million for 5 months at the 5-month spot eurodollar rate
- *Lend* (long deposit) $1 million for 2 months at the 2-month spot eurodollar rate
- *Lend* (long forward deposit) $1 million two months from now for 3 months at the rate locked in by *purchasing* 1 eurodollar futures contract today.

The forward rate is *locked in* in the sense that if rates rise (fall) in the future, the gain (loss) that will be realized on the 3-month forward deposit contracted in two months will be offset by a capital loss (gain) on the futures contract. (Remember that in a futures contract, futures price=100-LIBOR, so that higher rates mean lower price.)

Caveats. Futures prices that are out of line with their theoretical fair values represent valuable, low-risk money-making opportunities. However, there are actually a number of simplifying assumptions embedded in this example. There are several points that would need to be taken into account to formalize this treatment:

- The exact offset between the synthetic forward (the first two segments of the above trade) and the futures contract requires that the contract be held to expiration. It assumes that there is full *convergence* of cash and futures rates at expiration -- i.e., the forward rate must track and eventually coincide with the cash rate.

- Some interpolation is required to calculate the implied forward rates as LIBOR rates may not be quoted for maturities that exactly coincide with futures expiration dates. Thus, the calculations may not be exact. This is particularly likely to be the case with more deferred contracts.

- The appropriate bid and offer rates need to be applied when using the above formulae. The wider the bid-offer spread, the more the futures rate can deviate from its theoretical value without creating arbitrage opportunities.

- Because the gains and losses on futures contracts are settled daily rather than upon expiration (as is the case with forwards), the above formula is not exact. A proper futures valuation formula would need to reinvest the expected futures gains and losses (variation margin) to the investment horizon. Note that there is a systematic bias against the long: the long generates profits (and hence invests margin income) in low rate environments while he sustains losses (and hence needs to finance margin) in higher rate outcomes. The reverse is true for a short. The implication is that a eurodollar contract trading at exactly the implied forward rate is actually expensive: the long should buy it a little cheaper to compensate him for this bias. This also means that in the above example the correct number of futures to purchase is slightly different from one (but, of course, one could not buy fractional contracts anyway). Adjusting the required number of futures for this factor is commonly referred to as *tailing*.

- The costs of engaging in such arbitrage trades is not the same for all market participants. Not all investors may be in a position to "short" deposits (i.e., borrow) -- in fact, only banks are in a position to do so. Non-financial institutions cannot arbitrage "cheap" futures by buying futures and lending funds because they are not lending institutions. We don't need that all investors be able to engage in two-way arbitrage to ensure fair pricing; what is important is that there be a sufficient number of market players with the capacity to do so.

Futures strip trading. In the previous example we only used one futures contract that matched up with the second three-month period. We can extend our horizon beyond six months by incorporating more futures contracts. For example, one could match the cash one-year LIBOR rate against a sequence or *strip* of a short cash deposit to the nearest futures expiration date (known as the *stub*, which would have a maturity of up to three months given the contract's quarterly expirations) and a sequence of the three front 3-month eurodollar contracts. Thus, futures arbitrage can be performed with any eurodollar deposit maturity that falls within the range of available futures contracts.

Constructing the futures strip: an example. One month before the expiration of the nearest futures contract, the ten-month strip rate would be calculated by combining the one-month spot cash rate (r_1) with the futures rate on the three nearest futures contracts (call them r_{f1}, r_{f2} and r_{f3}, each computed as 100 minus the price of the corresponding contract) according to the following formula:

$$\text{strip rate} = \left([1+r_1(30/360)][1+r_{f1}(90/360)]\times[1+r_{f2}(90/360)]\times[1+r_{f3}(90/360)] - 1\right)\times(360/300)$$

This produces an *annualized* strip rate, which can be compared against the cash LIBOR rate of corresponding maturity (r_{10} -- if it existed).

To compute this expression, we need information on the LIBOR yield curve and on the prevailing price of eurodollar contracts. Suppose that the one-month and ten-month LIBOR rates stand at 4% and 4.25% respectively, and that the price of the three front eurodollar contracts stand at 96.02, 95.92 and 95.71, respectively. In terms of our notation, we find that r_1=4%, r_{10}=4.25%, r_{f1}=100-96.02=3.98%, r_{f2}=100-95.92=4.08% and r_{f3}=100-95.71=4.29%. Plugging these numbers into the above expression results in a strip rate of 4.16%, which exceeds the value of r_{10}. Thus, we would be worse off investing in a 10-month deposit directly rather than "creating it synthetically" by investing in a one-month deposit and locking in the rate on the subsequent nine months using futures. Alternatively, we could arbitrage the difference by *shorting* the 10-month deposit with the less attractive rate and *going long* the strip (i.e., buying each of its constituent parts, in other words, the one-month deposit and the sequence of three eurodollar contracts).

C. Risk management and hedging

Overview. Eurodollar contracts are extremely useful hedging devices precisely because they can be chained together into strips that behave like longer-term assets and liabilities, as illustrated above. Eurodollar contracts on the CME extend out to seven years. Trading activity in the outer years --on which open interest is still substantial-- is in fact dominated by hedge users, especially of swap portfolios. Broadly speaking, a hedge consists of a proportional amount of the futures contracts and of the underlying. Futures-based hedges are relatively static --i.e., they do not require much dynamic adjustment-- because of the relatively stable relationship between the futures and the underlying.

Hedging mis-matches. The exactness of a eurodollar-based hedge has to do, aside from the optimality of trade construction, with how closely the rate underlying eurodollar futures (i.e., 3-month LIBOR) corresponds with the rate being hedge. There are two particularly prevalent types of mis-matches:

- *timing* mis-match: reset or maturity dates of the hedged asset or liability versus futures expiration dates.

- *basis* mis-match: the nature of the rate underlying the hedged asset or liability versus 3-month LIBOR.

Devising the hedge ratio. The number of futures contracts used to hedge (a particular or a portfolio of) financial instruments is called the *hedge ratio*, which is determined by:

Hedge ratio = scale factor × basis point value factor × volatility factor

- *Scale factor:* it is the ratio of the notional or principal amount of the asset being hedged to the futures contract size.

- *Basis point value factor:* it is the ratio of the change in the dollar value of the hedged asset to the change in the dollar value of the futures contract *for a one basis point change in the interest rate.* In other words, it measures the relative sensitivity of the hedged asset and the hedge instrument to changes in the interest rate environment.

- *Volatility factor:* it takes account of the possibility that the yields on the hedged asset and the futures contract do not move one-for-one or exactly together. That is, it measures the relationship between the yield on the hedged asset and the yield of the hedge instrument. Often this is accomplished using regression analysis.

Examples of risk management applications. We illustrate the concept of hedging with five examples: (a) hedging coupon payments on a floating-rate liability, (b) locking-in a rate for future commercial paper issuance, (c) hedging a fixed-rate asset, (d) hedging (or replacing) an interest rate swap, and (e) asset/liability or portfolio duration management. The first case is discussed at length for illustrative purposes, while the others are treated mostly at an intuitive level.

(a) Hedging coupon payments on a floating-rate liability

Nature of the problem. Suppose a corporation has a $5 million, 3-year loan from Sanwa Bank repriced every six months based on 6-month LIBOR. The corporation believes interest rates have bottomed out and are going to increase. The corporation would like to hedge the interest rate risk associated with paying higher interest costs on subsequent resets of the loan. How can the corporation use futures to hedge the risk?

Intuition. Since the corporation would like to generate profits in the futures market to offset the expected losses in the cash market as interest rates rise, they would *sell* futures. As rates rise, futures prices fall (remember: futures rate=100-price). This is the qualitative answer. But just how many and which contracts should be sold?

Hedge ratio. Using the framework presented above, the hedge ratio would be calculated as follows.

- *Scale factor:* given a $5 million loan size and eurodollar contract size of $1 million, the scale factor is $5,000,000/$1,000,000 = 5.

- *Basis point value factor:* The value of a one basis point change in 6-month LIBOR (per million of principal) is given by:

  ($1,000,000)×(1 b.p.)×(6mo/1yr) = $1,000,000×.0001×(180/360) = $50,

  while the tick value of a eurodollar futures contract is $25. Thus, the basis point value factor is $50/$25 = 2.

- *Volatility factor:* we can expect the yield on the loan (indexed on 6-month LIBOR) and the yield underlying the eurodollar contract (3-month LIBOR) to move essentially one-for-one as both have similar credit characteristics. (Essentially, we are assuming that the shape of the yield curve structure in the 3-month to 6-month segment remains constant.) Thus, we can set the volatility factor to 1.

Combining these three factors, we find that the appropriate hedge ratio is 5×2×1 = 10. This is the number of contracts for *each* LIBOR repricing the corporation would like to hedge against.

Which contracts to sell. Having determined the hedge ratio, we still need to determine which contract months the corporation should use. Say that in January we wanted to hedge the next coupon reset, which occurs in June (for the June to December period). The June and September contracts seem obvious candidates as they span the period over which the repricing applies. The two most basic options are:

- *Stack* the position, i.e., hold all the position in a single contract month. For instance, sell 10 June contracts, and upon their expiration in June *roll* the 10 contracts over into the September contract.

- *Strip* the position, i.e., spread the 10 contracts over the two relevant contract months. Accordingly, sell 5 June contracts and 5 September contracts.

Either of these approaches will provide an adequate hedge against parallel shifts in the yield curve (i.e., if 3- and 6-month LIBOR rise or fall by the same amount). However, the two approaches will yield different results if these two rates shift by different amounts. The stack hedge will be advantageous if you believe the yield curve will flatten while the strip rate should be used if you believe the yield curve will steepen.

(b) Locking-in a rate for future commercial paper issuance

Nature of the problem. Suppose the corporation expects to issue $5 million in commercial paper (with semi-annual interest rate resets) in the near future, but at the same time it expects rates to rise. How can futures be used to *lock in* or *fix* borrowing costs without advancing the date of actual issuance?

Intuition. A short futures position will generate profits if rates rise, which would offset higher future borrowing costs. Thus the corporation will again want to *sell* futures. This hedge will be more risky since 3-month eurodollar rates are not as highly correlated with commercial paper rates as with 6-month LIBOR. In this case it would be advisable to use a volatility factor in the hedge ratio formula, on the basis of some statistical analysis of the correlation between 3-

month LIBOR and commercial paper rates. The scale factor and the basis point value factor would be the same as in the previous example.

(c) <u>Hedging a fixed-rate asset</u>

<u>Nature of the problem</u>. Suppose the corporation owns a $5 million, 3-year Treasury note as an asset. How can futures be used to maintain the value of this investment under a shifting interest rate environment (changes in the yield curve structure)?

<u>Intuition</u>. The cash flows of any Treasury note can be replicated using strips of eurodollar contracts (along with a long cash position to the first contract expiration date, as shown in the previous section). In fact, one strip can be constructed for each Treasury note coupon date to maturity. Since the corporation is long the note, it will want to be short the strips --i.e., *sell* the constituent futures contracts-- for hedging purposes.

<u>Hedge ratio</u>. The *scale factor* will be the same as above, i.e., $5,000,000/$1,000,000 = 5. The *basis point value factor* is equal to the dollar duration (modified duration times price inclusive of any accrued interest) of the note divided by $25 (the basis point value of the futures contract). A volatility factor of 1 would implicitly assume two things: (i) that yield curve shifts tend to be parallel (i.e., the 3-month rate on which the futures is based and the 3-year rate of the note tend to move together), and (ii) the credit spread between Treasurys and LIBOR (or bank credit) will be constant. Given the implausibility of these assumptions, a volatility factor different from one would probably need to be used.

<u>Alternative methodology</u>. The methodology applied above will hedge the duration of the asset but may perform more or less well depending on how the yield curve itself changes. The crucial issue is that the above methodology is not precise as to which contracts should be bought. A more exact procedure to calculate the number of contracts over each contract month is to: (i) express the net present value of the hedged asset as a function of a strip of spot and forward rates; (ii) find the change in the net present value of the swap from a one-basis-point change in each of the individual forward rates; and (iii) divide each answer by $25 (the basis-point value of a eurodollar contract) to find the number of futures needed in each respective contract month. The total number of contracts that result from this methodology will be the same as that using the hedge ratio formula given above. This methodology provides an *allocation* of futures over contract months --in addition to the total requisite number of contracts-- that will hedge against any shift in the yield curve. Note that the total *number* of contracts to be sold is the same under the two methodologies.

(d) Alternative to interest rate swaps (or, hedging a swap)

Nature of the problem. How can eurodollar futures be used to mimic an interest rate swap? If this can be done, then eurodollar futures could be used either to hedge or to replace interest rate swaps.

Intuition. An interest rate swap is essentially a bundle of strips of interest rate forwards (otherwise know as *forward rate agreements* or FRAs). Being long (short) the strip of forwards is tantamount to receiving (paying) fixed and paying (receiving) floating. Notice that if you are receiving the fixed rate in a swap or are long interest rate forwards, you benefit from reductions in interest rates and are harmed by interest rate hikes. Given the close relationship between futures and forwards, it is clear that a given swap position can be replicated using eurodollar futures. The two methodologies outlined in the previous example can be used to hedge a swap.

(e) Asset/liability duration management

Nature of the problem. Suppose that the maturity (or, more properly, *duration)* of a corporation's liabilities is shorter than that of its assets. The finance director might be worried that if interest rates rise, the value of the assets will drop precipitously relative to the value of its liabilities. How can futures be used to match the duration of assets and liabilities?

Intuition. He can create a synthetic liability using a short futures position. By *selling* futures, he can increase the sensitivity of the liabilities to rate changes up to the point where it matches that of the assets. The basic approach is to sell a eurodollar contract for each $25 in dollar duration needed to cover the asset/liability duration gap.

D. Expressing a market view

Overview. Given the inherent characteristics of international bank ("euro") deposit contracts, they appear to be very much a hedger's contract. However, they are also very well suited as a mechanism for expressing views on the front-end of the market. Each eurodeposit contract represents a three-month segment of the yield curve in a particular currency. Thus, eurodeposit contracts permit isolation of expected events (whether of a fundamental or technical nature) on a very precisely-defined segment of the yield curve.

Euros and central bank watching. Eurodeposit contracts are particularly useful for trading around expected central bank actions for three (related) reasons. First, because of the high liquidity of the front-end contracts. Second, because the transmission of central bank actions from its policy instruments (money supply or specific short bank rates) to three-month bank deposit rates is fairly direct. And, third, because short-term bank rates are used by many central banks if not as policy targets at least as policy indicators. For these reasons, the eurodeposit futures contract table, with a sequence of contracts three months apart in time, can be "read" as the market's view on likely central bank actions in the short-term. Contracts in the outer years are less linked to expected central bank actions because they tend to be dominated by expectations on a range of other economic variables like general economic performance and longer-term inflationary expectations.

Nature of view being exploited. Despite the apparent simplicity of eurodeposit futures, they permit the expression of market views by traders on a range of dimensions. Eurodeposit futures are used most frequently to express views on the following:

- General market direction. Eurodeposit futures permit the lengthening or shortening of the duration of portfolios according to expectations on market direction. Bets on falling interest rates would be undertaken by purchasing individual contracts or strips of contracts, while bets on rate hikes would be expressed by shorting individual contracts or strips. These trades tend to be *outright,* that is, with no offsetting positions.

- Timing of market changes. Eurodeposit futures trades can be constructed so as to bet on the direction as well as on the timing of expected changes in money market rates (e.g., following an anticipated central bank action). For example, buying the front June contract and selling the front September contract constitutes a bet that interest rates will rise *in the three months* between June and September to the extent that the yield curve reflects expectations of future interest rates. More formally, this trade is premised on the expectation of a *steepening* of the yield curve. Such *calendar spread trades* are not affected by *parallel* shifts in the yield curve (under which the price of all contracts move by the same amount), but do capture a flattening or steepening of the yield curve. If one wanted to bet on the expected timely movement of a particular contract relative to its neighboring contracts rather than on a progressive flattening or steepening, the trade could be constructed as a *butterfly*. In this case, that contract would be bought (sold) and *both* neighboring contracts would be sold (bought).

- Co-movement across international markets. Alternatively, one can bet on what rates might do in one country *relative* to what they do in another country by putting on a *country spread trade*. For instance, if rates are higher in Germany than in the US, a *convergence trade* would consist of going long (a single or a strip of) euromark contracts and shorting (the same) eurodollar contracts. This trade wins if rates in Germany fall relative to trades in the US (i.e., if rates in the country in which you are long fall by more than rates in the country where contracts are sold).

- Credit spreads. The view may not be on the overall level of interest rates but rather on the credit spread between (high quality private) bank deposits and Treasury liabilities. This so called TED spread (for Treasury-EuroDollar) can be played in the U.S. by going long and short one each of a eurodollar contract (bank credit) and a T-bill contract (Treasury credit). In non-dollar markets where a T-bill contract does not exist, a *synthetic TED* trade may be entered into by constructing a eurodeposit contract strip that exactly matches the cash flows of a particular Treasury security. The difference in the yield between the cash Treasury security and the euro contract strip is equal to the TED spread. Going long one and shorting the other is a trade on the credit spread.

Hedge ratios. When one constructs spreads and butterflies, one generally wants to insulate the trade from general market direction. This is done by having the same number of long as of short contracts. Accordingly, a spread trade will have equal number of contracts on the two *legs*; a butterfly will have half as many contracts on each of the two *wings* as in the *body*. These hedge ratios ensure that there is no net basis point value in the trade. However, they will insulate the trade only against *parallel* movements in the yield curve.

Caveats. Futures rates embodied in international bank deposit contracts should not be interpreted systematically as representing the market's "best guess" of the future spot rate. Empirical analysis has shown that futures rate are in fact *biased estimators* of future spot rates. However, what matters for our purposes here is only that this bias be fairly constant so that changes in market expectations do result in changes in futures rates. A second caveat is that eurodeposit trades as those described above are mostly bets on changes in market expectations on interest rates rather than on changes in interest rates themselves. Expectations may not change in the manner anticipated by the trader even if all "fundamental" variables seemed to indicate otherwise.

III. Intermediate- and Long-Term Interest Rate Futures

A. Contract specifications

Deliverable securities. Unlike international bank futures contract, bond futures are settled at expiration with physical delivery. Also unlike the T-bill futures contract, bond futures contracts generally allow for a range of bonds to be delivered against them. For example, U.S. Treasury bond futures contracts allow delivery of any U.S. T-bond that has at least 15 years remaining to maturity (or to first call if the bond is callable); there may be as many as several dozen securities in the *deliverable basket,* all with different maturities and coupons. Providing for a deliverable basket rather than a single deliverable bond is designed to prevent manipulation of the futures price at delivery given the relatively small size of issuance of any specific T-bond. The range of deliverable securities for bond futures is analogous to the idea of specifying a *contract grade* for futures on agricultural commodities like wheat which provide for delivery in different grades of quality (and location) of the commodity.

Conversion factors. Given the potential diversity of bonds in the basket, some method must be devised to make them comparable. More precisely, they must all be made roughly equally likely of being chosen for delivery. To achieve this, each deliverable bond is assigned a *conversion factor* designed to "handicap" it or put it on an equal footing with the other bonds in the basket. In the case of the U.S. T-bond future, conversion factors are given by price at which each bond eligible for delivery will have a yield of 8% to maturity (or first call). This choice of conversion factor determination is admittedly quite arbitrary. But the important thing is to make the bonds *roughly* comparable, not necessarily equal. Conversion factors are set by the exchange, they are unique to each bond and to each delivery month, and are constant throughout the delivery cycle.

Delivery cycle. Delivery can take place at any time within a pre-specified *delivery period* once trading in the contract has ceased. Thus, at futures expiration there is uncertainty not only on the actual bond that will be delivered but also on the specific timing of the delivery. Of course, bond futures positions can also be unwound prior to delivery by an offsetting futures transactions. Because this is more convenient for most futures users than physical delivery, few contracts actually go into delivery.

Futures invoice price. When a bond is delivered into the bond futures contract, the receiver of the bond pays the short an invoice price equal to the futures price times the conversion factor of the particular bond chosen by the short, plus any accrued interest on the bond:

futures invoice price = futures price×conversion factor + accrued interest

The short's options. It is the party that is short the contract who decides exactly which bond to deliver and when. Confusingly enough, the short is said to be long the ***delivery option.*** As the prices of the various bonds in the deliverable basket fluctuate in the market, one of them will be cheaper to deliver than the others (adjusting for their different conversion factors and other factors that will be explained below). The short will exploit the fact that conversion factors are not perfect handicaps to deliver at lowest cost.

What is the underlying? The implication is that there is no single underlying bond but rather a pre-specified range of potential underlying bonds. The underlying can change from one day to the next, depending on which bond is most likely to be delivered. The price of the contract will be driven by the price of the cheapest-to-deliver but may differ if there is a possibility of a subsequent "switch" in the cheapest-to-deliver. More formally, the futures price behaves like a complex hybrid of the bonds in the deliverable set, depending on their respective likelihoods of being delivered. Eventually, at futures expiration, the price of the future will be determined only by the price of the cheapest-to-deliver bond since there will be no option value left.

Other contract terms. Exchanges set other futures contract terms as follows; the concrete specifications of the U.S. T-bond contract are shown in parentheses for illustrative purposes. The *contract size* defines the par amount of the bond that is deliverable into the contract ($100,000 for U.S. T-bonds). *Price quotes* are either decimal or in fractional terms (32nds of a point). The *tick size* is the minimum size of price change (1/32nd of a point). The *tick value,* the dollar value of a tick, is given by the contract size and the tick size ($100,000/32=$31.25). The *daily price limit* is the maximum permissible price change within a day that triggers an automatic premature closing of trading in the contract for that day. *Delivery months* on bond futures contracts are quarterly (March, June, September and December). The exchange will also set daily *trading hours,* the *last trading date* and the *last delivery period* (one month).

Other U.S. medium- and long-term interest rate contracts. The U.S. T-bond, traded at the CBOT since 1977, was the first future on long-term interest rates. Since then three futures contracts have been established on U.S. Treasury notes: a 10-year, a 5-year and a 2-year contract. They all have similar characteristics to their forerunner. Throughout this chapter we refer to notes as bonds since their distinguishing feature is only a shorter maturity.

International bond futures contracts. Since 1982, bond futures contracts designed along the lines of the U.S. T-bond contract have spread internationally. For illustration purposes, the table below lists the main international bond futures contracts, where they are traded and the description of their deliverable set.

Contract (Exchange)	Deliverable Set
Long Gilts (LIFFE)	Non-callable British government bonds (gilts) that have a remaining maturity of at least 10 years but no more than 15 years as of the first calendar day of the delivery month.
Bunds (LIFFE)	Non-callable German government bonds (bunds and Treuhand bunds) that: (i) have a remaining maturity of at least 8.5 years but no more than 10 years as of the 10th day of the delivery month; (ii) pay interest annually; (iii) can be delivered through the Kassenverein system; and (iv) are listed on the Frankfurt Stock Exchange.
JGBs (TSE)	Japanese government bonds (JGBs) listed on the Tokyo Stock Exchange that have a remaining maturity of at least 7 years but no more than 11 years at delivery.
Notionnel (MATIF)	French government bonds (OATs) with at least 7 years but no more than 10 years remaining to maturity; issues with coupon detachment less than 15 days after settlement are not deliverable.
BTPs (LIFFE)	Italian government bonds (BTPs) with at least 8 but no more than 10.5 years remaining to maturity as of the 10th calendar day of the delivery month.

Generally speaking, the deliverable basket for the non-dollar contracts are more homogeneous and the delivery time window narrower than they are for the U.S. Treasury contracts. Thus, there is much less option value for the short in terms of what security to deliver and when.

B. Pricing and arbitrage

Cash-futures relationship. Similar to short-term interest rate contracts, there is an arbitrage relationship which holds the prices of the T-bond futures contract to the cash market. Understanding the relationship between a futures contract and the deliverable basket is crucial to understanding the drive behind the arbitrage. It is the delivery option of the short that makes valuing bond futures more complex than valuing international bank (euro) deposit futures.

The basis. The basis is the difference between a bond's price and the futures invoice price (as defined above). In other words, it is the difference in cost between buying the bond in the cash market and buying a futures contract on it and having it delivered into the contract at expiration. Accordingly, we define the *gross or raw basis* as:

Gross basis = dirty cash price - futures invoice price
= clean cash price - (futures price×conversion factor)

since dirty (or full) price = clean price + accrued interest. The basis is generally quoted in 32nds rather than in decimal units -- this conversion is performed simply by multiplying the decimal basis by 32.

Basis arbitrage at futures expiration. At futures expiration, the gross basis must be equal to zero. Otherwise there would be instantaneous riskless profit opportunities. Suppose, for instance, that the gross basis was negative (positive). Then one could: (i) buy (sell) the cheapest-to-deliver bond in the cash market; (ii) sell (buy) a bond futures contract; and (iii) immediately deliver (receive delivery of) the cash bond against the short (long) futures position. If such a profit opportunity arose, the cash bond price would be bid up and the futures price would be bid down, which would tend to drive the gross basis up (down) to zero.

Refining the basis calculation: the net basis. Prior to expiration, however, the gross basis can differ from zero because of the financing cost of undertaking the arbitrage trade described above. In particular, the long cash bond position would need to be financed to the futures expiration date at the prevailing *repo rate*. The gross basis needs to be adjusted by this *carry* (or financing) factor, to yield the *net* basis:

net basis = gross basis - carry (all generally quoted in 32nds)

Calculating the carry. The carry is the profit or loss from holding cash bonds. It is given by the difference between the coupon income made by holding the bond and the rate paid to finance the bond:

carry = coupon income - financing cost

where coupon income = coupon/2×(days to futures delivery)/(days between coupons) and financing cost = (price + accrued interest)×(repo rate)×(days to futures delivery)/360

The above formulae apply to the U.S. case, where Treasurys pay semiannual coupons according to an actual/actual day count convention, and money market rates pay according to an actual/360 day count. They also assume for simplicity that no coupon is paid on the bond prior to the futures delivery date. To make carry comparable to the gross basis, it must be converted into 32nds in similar fashion to the gross basis.

Interpreting the carry. If carry is positive, as it will be if the yield curve is positively sloped (i.e., higher yield on longer-term bonds than on shorter-term financing rates), one can earn net interest income holding a bond for future delivery. If an investor who is long the cash bond and short the corresponding futures contract faces a positive carry, he will be willing to face an adverse (positive) gross basis -- so long as the net basis is not positive. Conversely, if the yield curve is negatively sloped, carry will be negative and one will lose interest income from being long the cash bond.

Carry in short bond positions. The same reasoning applies, but in reverse, if instead of going long the bond and short the future, one shorts the bond and buys the future. The only difference is that instead of using a repo (financing) rate one will need to use a *reverse repo* (investment) rate. With a short bond position, a positively- (negatively-) sloped yield curve induces carry losses (gains) which need to be compensated with a positive (negative) gross basis.

Arbitraging the net basis. Arbitrageurs will tend to drive the net basis towards zero. Basis trading is building simultaneous offsetting positions in the cash and futures bond markets. The ratio of cash bonds to futures contracts is given by the bond's conversion factor, since the trade as described above was premised on delivering the bond position exactly into the short futures position. A substantially positive net basis can be exploited by selling (shorting) the cheapest-to-deliver bond and buying a futures contract -- by convention, this is called *selling* the basis or going *short* the basis. Conversely, a substantially negative net basis gives an opportunity to buy the cheapest-to-deliver and sell a futures contract against it -- this is called *buying* the basis or going *long* the basis.

Fine-tuning the net basis. Technically, the arbitrage-free level of the net basis prior to futures expiration is not zero but slightly positive, meaning that from a strict carry stand-point futures prices are usually too low. This is because of the option value held by the short future position stemming from the possibility of a switch in the cheapest-to-deliver.

Basis trading: summary. It is basis traders who anchor the bond futures price on the basis of the cash bond market. The challenge in basis trading is in understanding what determines the cheapest-to-deliver bond among the delivery basket. Sophisticated basis traders apply fancy option valuation techniques to understand just how positive the net basis needs to be. The net basis changes with time: time weakens the short's option value and so the net basis converges to zero.

An alternative viewpoint: the implied repo rate. The net basis tells you by how much it is cheaper (in 32nds) to obtain bonds at the futures delivery date by buying a futures contract and taking delivery of the bond rather than by buying it directly in the cash market today and financing it at the prevailing repo rate to the futures delivery date. Alternatively, one could look at the same data by asking: what would be the break-even financing rate that would make me indifferent between owning a bond future and owning the actual bond? We define the implied repo rate (IRP), then, as the repo rate that sets the net basis equal to zero. Simple manipulation of the above relationships with the constraint of net basis = 0 produces the following formula for the IRP (assuming no coupon payments prior to the futures delivery date):

IRP = (futures invoice price/bond purchase price - 1)×360/(days to futures delivery)

IRP and the determination of the cheapest to deliver. To repeat, the IRP is the theoretical return one would obtain from buying the cash bond, selling futures short against it, and then delivering the cash bond into the futures. Obviously, then, of all the bonds in the deliverable basket, the one with the highest IRP will be the one the short will select as the cheapest-to-deliver. Note that the cheapest bond to deliver need not be the bond with the lowest market price because one needs to adjust for the conversion factors. The cheapest-to-deliver bond is the one with the lowest purchase price *relative* to its futures invoice price (notice that the inverse of this ratio is what drives the IRP in the formula above).

Basis calculation: an example. Suppose that the June 1993 U.S. T-bond futures contract is trading at a price of 111-00 (i.e., 111 and zero 32nds) as of March 25, 1993. Suppose, further that on that date the cheapest-to-deliver bond is the 7.125% of February 2023, which is trading at a clean price of 104-16.8 (equal too 104.525 in decimal terms) and which has a conversion factor of 0.9014. The bond pays semiannual coupons each February 15 and August 15, and the futures is expected to be settled on June 30, the last delivery date. The term repo rate to June 30 is 3.10%p.a.

The sequence of basis calculations are as follows:

Gross basis = clean price - (conversion factor×futures price)
= 104.525 - (0.9014×111.000) = 4.4696 = 4.4696×32 *in 32nds of a point*
= 143 *32nds of a point*

Accrued interest as of 3/25/93 = (coupon rate/2)×(days from last coupon, i.e., from 2/15/93 to 3/25/93)/(days in coupon period, i.e., from 2/15/93 to 8/15/93)
= (7.125/200)×(38/181) = 0.748

Dirty price of bond = clean price + accrued interest = 104.525 + 0.748 = 105.2729

Futures invoice price = futures price×conversion factor + accrued interest
= 111×0.9014 + 0.748 = 100.8033

Coupon income to futures delivery = (coupon rate/2)×(days to futures delivery, i.e., from 3/25/93 to 6/30/93)/(days in coupon period, i.e., from 2/15/93 to 8/15/93)
= (7.125/200)×(97/181) = 1.909

Financing cost = dirty price×(repo rate/100)×(days to futures delivery)/360
= 105.2667×(3.10/100)×97/360) = 0.879

Total carry = (coupon income - financing cost)
= 1.90919 - 0.87927 = 1.030 = 1.030×32 *in 32nds* = 33 *32nds of a point*

Net basis = gross basis - total carry = 143 - 33 = 110 *32nds of a point*

This is the amount that can be earned by going long the futures contract and short the cash bond.

Potential risks. If you sell the basis, you encounter two potential risks. First, since you are short the cash bond, there is financing risk unless the repo rate is locked in until the futures delivery under a *term repo*. Otherwise, you are exposed to that particular bond going on *special* in the repo market, in which case its repo rate might increase dramatically. Second, since you are long the future, the cheapest-to-deliver (which is chosen by the short) might change. Also, basis trades might not work if there is no cash-futures convergence at expiration of the futures contract. Finally, a basis position may not be duration neutral as the conversion factor is only an approximation of the futures' duration. Hence, a long and short position in bonds and futures, even if weighted by the conversion factor, might still be sensitive to market movements. Once could devise a more appropriate hedge ratio (using option-adjusted duration for the futures) at the cost of introducing basis risk.

C. Risk management and hedging

Basic risk management functions. Bond futures are often used as a vehicle for hedging *price risk* or *duration.* An excessive exposure to intermediate- and long-term interest rates can be offset by buying or selling bond futures contracts. One might want to hedge the price risk associated with a single transaction or instrument, or on a portfolio or firm basis.

Hedge ratio. The construction of the hedge ratio for bond futures follows the same logic as that for international bank futures contracts developed in Chapter 2. Recall that he basic formula is:

Hedge ratio = scale factor × basis point value factor × volatility factor

The scale factor is the ratio of the notional or principal amount of the asset being hedged and the futures contract size. The basis point value factor is the ratio of the change in the dollar value of the hedged asset to the change in the dollar value of the futures contract for a one basis point change in the interest rate. The volatility factor can be set to one if bond futures are used to hedge interest rate risk of roughly the same credit characteristics and in roughly the same yield curve segment.

Computing the basis point value factor: a simple approach. The numerator, the change in the dollar value of the hedged asset for a one basis point change in the interest rate, is given by the asset's (or portfolio's) *dollar duration.* The dollar duration of a bond is given by the product of its *modified duration* and market value (*dirty* or *full* price). Because futures' market value is zero (due to their being marked-to-market), their dollar duration cannot be defined as for a bond. The solution is to treat the bond futures contract for the purposes of measuring price risk as the cheapest-to-deliver bond with face value equal to the contract size. The duration of the future, then, is proxied by the duration of the cheapest-to-deliver bond at futures expiration adjusted by the conversion factor.

Computing the basis point value factor: a more complex approach. The above approach produces a reasonable hedge as long as the cheapest-to-deliver bond does not change during the life of the hedge. However, in determining the effect of a yield change on the price of the cheapest-to-deliver one would also need to factor in its effect on the short's choice of cheapest-to-deliver. This methodology produces what is known as an *option-adjusted hedge ratio* (and an option-adjusted futures duration).

Hedging examples. We treat here two examples of the use of bond futures as hedge instruments: (a) hedging a long position in the cheapest-to-deliver bond, and (b) a fixed-income anticipatory hedge.

(a) Hedging the cheapest-do-deliver bond

Nature of the problem. Suppose we wanted to hedge a long position of $100,000 par value in a particular bond that happens to be the cheapest-to-deliver bond for a particular bond contract. How many futures contracts need to be sold against the bond position to eliminate its sensitivity to price risk?

Hedge ratio. The scale factor is one since the futures contract size is equal to the cash bond position to be hedged. The volatility factor is also one since the underlying for the futures price is basically the cheapest-to-deliver, which is the bond that needs to be hedged. The basis point value factor is equal to the bond's conversion factor. This is because, as explained above, the dollar duration of a bond futures contract can be approximated by the duration of the cheapest-to-deliver divided by its conversion factor. This implies that the ratio of the bonds to the futures' dollar duration is just the conversion factor. To sum up, then, the hedge ratio is given by the conversion factor -- this is the hedge ratio used (implicitly) in the construction of basis trades as described in the previous section.

(b) Fixed income anticipatory hedge example (Excerpted from Treasury Futures for Institutional Investor, Chicago Board of Trade, 1990.).

Nature of the problem. On July 1, an insurance company enters into a commitment to sell a 20 million Guaranteed Investment Contract ("GIC") with a five year duration to a corporation. The GIC will be effective on October 1 and will yield a return of 9%. How can the insurance company protect itself from a drop in interest rates (rise in price) between the time of commitment (July 1) and the time of funding (October 1) using futures?

Hedge ratio. The scale ratio is given by $20,000,000 (the value of the GIC) divided by $100,000 (the 5-year futures contract size), or 200. Suppose that the modified duration of the corporate bond portfolio to be hedged is 4.92 and its market value (including any accrued interest) is $11.77 million. Then the basis point value of the corporate bond portfolio (per $100,000 of face value) is $\$11.77 \times 4.92 = 57.918$. Suppose, further, that the basis point value of a futures contract (based on the cheapest-to-deliver) is $41.37. Then the basis point value factor is 57.918/41.37 = 1.4, and the appropriate hedge ratio will be 200×1.4=280 contracts a (assuming a volatility factor of 1). The insurance company will buy this number of 5-year T-note futures so that, if by October 1 rates have dropped, the insurance company will offset the higher cost of funding with gains on its futures position.

Similar application: hedging underwriting and distribution risk. For primary government securities dealers, the futures market is a ready outlet for laying off the risk in bidding for and distributing the large volumes of Treasury securities that are auctioned off periodically. Similarly, underwriters of corporate bonds would use futures to hedge the market risk of their underwriting positions; however, the credit risk (difference between Treasury and corporate credit) would need to be taken into account by figuring an appropriate volatility factor in the hedge risk.

D. Expressing a market view

Types of trades. The third application of bond futures, trading on the basis of market views, requires by definition that not all risk be hedged. Bond futures, as was the case with international bank deposit futures, can be traded:

- *outright*, to express a view on market direction;
- in combination with other bond futures contracts, using *spreads* or *butterflies* that combine longs and shorts at different points in time or across countries; or
- in combination with the underlying (typically the cheapest-to-deliver bond) in what amounts to basis trades.

Outright trading. As was explained earlier, bond futures by themselves don't have duration. But because they track the cheapest-to-deliver bond (driven by basis traders), they contribute dollar duration to portfolios much along the lines of the cash bond. Going long the futures is a way of extending duration: it pays when the market is rallying and rates are falling. Shorting bond futures, on the contrary, reduces market sensitivity to rate movements and performs well in a bear market. Playing duration with futures fulfills the same objective as playing the bond market directly, but with the convenience of the futures market in terms of narrow bid/ask spreads, easy reversibility of positions and low cash requirements.

Spread trading. As a word of caution, it should be mentioned that bond future spread or butterfly trades are less straight forward in their interpretation than similar trades with international bank deposit futures. For instance, Interpreting a bond future *calendar spread* as a reading on a particular segment of the yield curve is made difficult by each contracts' particular sensitivity to shifts in the cheapest-to-deliver and to changes in the repo rate on the cheapest-deliver. In a similar vein, *cross-country spreads* may be driven by differences of the duration of their respective cheapest-to-deliver bonds than by the absolute level of long-term rates.

Basis trading. Trading the basis from the long side is relatively riskless if the position is held to the futures expiration date, as explained above. A basis trade can also be held for shorter time horizon but then the position is subject to risk at the unwind. A short-term basis position financed at an overnight rather than term rate constitutes a bet on basically two things: (i) the level of long-term rates (which determines which bond will be the cheapest-to-deliver since they each have different sensitivity to market rates according to their duration); and (ii) the evolution of short-term rates, and in particular whether the cheapest-to-deliver goes on *special* in the repo market. Short-term basis trading is in fact quite complex, and can be used to take on risk subject to one's views in addition to as an arbitrage play. Basis trades can be entered into directly (by playing the bond and futures markets simultaneously as discussed in Section B) or indirectly by replacing an existing long bond position with a long position in bond futures and short-term money market investments.

IV. Currency Futures

A. Contract specifications

Types of contracts. Foreign currency futures contracts are available on all major currencies against the dollar (e.g., GBP, CAD, DEM, JPY, SRF, AUD, etc.), most of which are traded at the CME and at LIFFE. In addition, there are futures on a USD *index* (i.e., average of *bilateral rates* against the dollar) at the CBOT. Finally, there are futures on *crosses,* i.e., bilateral exchange rates between two non-dollar currencies such as on JPY/DEM.

Contract specifications. Currency futures against the dollar, by far the most prevalent, tend to have quarterly contracts with delivery in March, June, September and December. They tend to require actual delivery, meaning that at futures settlement the long receives the currency of denomination of the future and pays dollars). Price quotes are on *American terms*, i.e., based on number of dollars per unit of foreign currency.

B. Pricing and arbitrage: International interest rate parity

Overview. As with interest rate futures, the prices of currency futures are bound by a basic arbitrage relationship with the underlying cash market. Arbitrage relations are cleaner with forwards than with futures because mark-to-market payments on futures introduce an element of reinvestment risk that cannot be fully hedged. However, in the case of currencies, the difference between forward and futures prices is less important than with interest rates. There is no financing bias against the long as was the case with interest rate futures if exchange rates are assumed to be uncorrelated with the *level* of interest rates. Below we establish the basic arbitrage relationship that is used by dealers to establish currency forward prices -- and which are a very good approximation for futures prices.

Interest rate parity. According to *covered interest rate parity,* the *actual dollar return* on fixed-income investment across currencies (with the same cash flow profiles and credit risk) should be the same if future currency exchanges are locked in with a currency forward. Otherwise, arbitrage opportunities would arise and capital would flow internationally to the high-return currency so as to equalize returns.

Interest rate arbitrage: an example. Suppose a dollar-based investor would like to invest \$1 for one year. If he places the money locally, after a year he will have $(1+r_{us})$, where r_{us} is the one-year dollar deposit interest rate. Alternatively, he can convert the \$1 into DEM at the prevailing spot exchange rate (call it e USD/DEM), invest it at the prevailing German term deposit rate (r_{dm}), and convert it back into dollars at the current one-year forward exchange rate (call it f USD/DEM). In this case, his return at the end of the year *in dollars* will be $f(1+r_{dm})/e$. Since annual interest rates and the spot and forward exchange rates are set at trade inception, the return in both cases is known with certainty. Thus, he will invest in whichever market offers the higher return: in dollars if $(1+r_{us})>f(1+r_{dm})/e$ and in deutschemarks otherwise. In the former case, investors worldwide will seek dollar investments and in the process bid up dollar interest rates and bid down deutschemarks -- which tends to equalize the return in both countries. Arbitrage will drive the two terms into equality, so that $(1+r_{us})=f(1+r_{dm})/e$, or, rearranging the terms,

$$f = e(1+r_{us})/(1+r_{dm})$$

Caveats. This is the basic formula for the pricing of currency forwards. Currency forwards are driven entirely by interest rate differentials in the two countries. There are several caveats that need to be borne in mind in applying this formula:

- The terms on the two interest rates have to match exactly (in terms of maturity, credit risk, compounding, etc.) If they do not, reinvestment risk can drive a wedge between the two returns.

- The relevant interest and exchange rate quotes need to take into account bid-ask spreads. This introduces a small range of forward prices within which arbitrage is not possible.

- Arbitrage can only take place if neither of the two countries have capital or exchange controls (and the market does not expect their imposition within the time frame of the trade).

C. Risk management and hedging

Types of foreign exchange exposure. Before hedging foreign exchange exposure, one must have a clear idea of how the exposure arises and what it means. There are three broad types of foreign exchange exposure:

- *Transaction exposure* arises from an open foreign exchange position from a specific commercial or financial obligation that has not yet settled. Unless they are hedged, exchange rate changes between the time of commitment and settlement will affect the home-currency value of the transactions. Examples are commercial import/export commitments, receivables and payables, foreign currency loans, repatriation of earnings from subsidiaries, etc. Calculation of the foreign exchange exposure is fairly straightforward as it only depends on the contractual terms of the specific transactions that give rise to the exposure.

- *Translation exposure* arises from an open foreign exchange position in a corporation's balance sheet. The exposure is given by the net value of assets and liabilities that are affected by (or *exposed to)* exchange rate movements. For instance, as a dollar-based multinational consolidates the financial statements of its subsidiary in Japan, it might want to hedge the amount by which the subsidiary's assets are more or less exposed to JPY-USD exchange rates than its liabilities. Calculation of the foreign exchange exposure is based on consolidated accounting information on the firm.

- *Operating or economic exposure* is defined as the change in the value of the firm that arises from unexpected movements in exchange rates. Unlike the previous two, this type of exposure is not created by past or present activities of the firm but rather by its future prospects. For instance an appreciation of the dollar relative to the yen impairs the ability of American producers to compete locally against Japanese imports and hence undermines their value -- even if the cash flows, assets and liabilities of the American producers are all denominated in dollars. This type of exposure is much harder to measure as it requires information on the firm, the market in which it operates, economic conditions and prospects, etc.

Examples. Below we provide two examples of currency hedges: (a) a transaction hedge, and (b) a translation hedge.

(a) Simple transaction hedge

Nature of the problem. Suppose an American producer has just sold (in December) DEM 30 million worth of personal computers in Germany, payment for which is to be received in 90 days (in March). What is the exchange rate risk and how can it be eliminated with futures? Suppose that the spot exchange rate is 1.5070 DEM per USD and that the March DEM futures are trading at 0.6568 USD/DEM (=1.5225 DEM per USD).

Intuition. You have a receivable, so you are attempting to hedge an asset that is denominated in DEM. You lose if the DEM 30 million yields fewer dollars in 90 days. That is, you lose if the USD/DEM rate declines, or if the DEM depreciates relative to the dollar, or if the dollar appreciates against the DEM. The futures exposure that has the opposite sensitivity is a *short* (i.e., selling) March DEM futures position. In other words, you sell forward the DEM that you know you will be getting in three months.

Hedge ratio. The notional value of a DEM futures contract is DEM 125,000. Thus, to hedge DEM 30 million we need DEM30,000,000/DEM125,000 = 240 contracts. If we do this we will have locked in an invoice value *in dollars* of DEM30,000,000× 0.6568USD/DEM = $19,704,000 in 90 days.

(b) Simple translation hedge

Nature of the problem. Suppose this American company has a subsidiary in Germany with a net exposed asset position in DEM of DEM 30 million. In other words, the subsidiary's assets denominated in DEM exceed its liabilities denominated in DEM by 30 million. How can futures be used to neutralize this foreign exchange exposure?

Intuition. Despite the different set-up, the intuition and hedge mechanics are identical to the previous case. When these amounts are consolidated with headquarters *in dollars*, the firm will lose value if the DEM depreciates relative to the dollar and will gain value if the DEM appreciates relative to the dollar. Here, too, we want to hedge a DEM 30 million exposure, so we will sell 240 contracts.

D. Expressing a market view

Outright trading. Futures are a natural instrument to express views on future exchange rate movements. For instance, going long the JPY contract (i.e., long yen and short dollars) is consistent with an expectation of an appreciation of the yen relative to the dollar. Conversely, shorting the contract is consistent with an expectation of a yen depreciation relative to the dollar. More formally, one should buy the JPY contract if one expects the yen to appreciate *more* than what is already expected (or *priced in)* by the market. Conversely, the contract should be sold if one expects the yen to appreciate more than what is expected by the market.

Spreads. One can fathom trades of increasing complexity by mixing in contracts of different underlying exchange rates or different maturities to construct spreads analogous to those discussed for interest rate futures.

V. Stock Index Futures

A. Contract specifications

The underlying instrument. Stock market indexes are time series designed to track the changes in the value of hypothetical portfolios of stocks. Stock indexes differ from one to another with respect to the range of stocks covered, stock weighting, and index computation. Indexes differ in composition because of the need to measure the price movements of the equity markets of different countries and different segments of each of these national equity markets. Though returns on stock indexes of the same country are often highly correlated over time, relative performance can vary sharply over periods such as a month or a quarter.

Index construction. The weight of a stock in an index is the proportion of the portfolio tracked by the index invested in the stock. The stocks in the portfolio can have equal weights or weights that change in some way over time. The most common weighting scheme is market value weighting, used for example in both the S&P 500 and NYSE indexes. Under this scheme the prices of each stock included are weighted by the number of shares outstanding divided by the aggregate number of shares outstanding of all stocks in the index multiplied by its corresponding prices. Finally, the method of averaging also influences the index value. Most market value-weighted indexes represent arithmetic averages. Another averaging technique (used, for example, in the Value Line index) is the use of a geometric mean or the nth root of the product of the individual stock prices, returns or values relatives.

Treatment of dividends. Stock indexes are not usually adjusted for cash dividends. In other words, any cash dividends received on the portfolio are ignore when percentage changes in most indexes are being calculated. This implies that percentage changes in stock indexes do not track total returns on the corresponding portfolio of stocks but, only price changes.

Futures contract specifications. All futures contracts on stock indexes are settled in cash. Physical delivery of stocks against a futures contract based on an index presents intractable difficulties. First, not every index correspond to a well defined portfolio of stocks (for example, those indexes constructed using geometric means). Moreover, it is not feasible to construct a broad market value weighted portfolio that is both of manageable size to be delivered and contains whole numbers of shares for all companies. To solve these problems stock index futures contracts are settle in cash and the underlying assets are defined to be an amount of cash equal to a fixed multiple of the value of the index.

Contracts traded. For illustration purposes, following is a list of the main international stock indexes and futures contracts on these indexes:

- *S&P 500* (CME). Based on a portfolio of 500 American stocks. The index accounts for 80% of the NYSE. The value of one futures contract is $500 times the index.
- *S&P 400 (CME).* Based on a portfolio of 400 American stocks. The value of one futures contract is $500 times the index.
- *NYSE composite futures* (NYSE). Based on a portfolio of all the stocks listed on the NYSE. The value of one futures contract is $500 times the index.
- *Major market index* (CME). Based on a portfolio of 20 blue-chip American stocks listed on the NYSE. The value of one futures contract is $500 times the index.
- *Value Line futures* (KC). Contains the prices of 1,700 American stocks. It does not correspond directly to any portfolio of stocks because of its use of geometric averaging. The value of one futures contract is $500 times the index.
- *Nikkei 225 stock average* (CME). Based on a portfolio of 225 of the largest stocks listed on the Tokyo Stock Exchange. The value of one futures contract is $5 times the index.
- *CAC-40 stock index* (MATIF). Based on a portfolio of 40 of the largest stocks listed on the Paris Stock Exchange. The value of one futures contract is FRF200 times the index.
- *FT-SE 100 index* (LIFFE). Based on a portfolio of 40 of the largest stocks listed on the London Stock Exchange. The value of one futures contract is GBP 25 times the index.

B. Pricing and arbitrage

Overview. Like futures on fixed income instruments and currencies, stock index futures prices should be related to the underlying cash market by a cost of carry relationship or, in other words, by the cash-forward relationship. Otherwise arbitrage trades are possible. As with interest rate and currency futures stock index futures prices and forward prices may differ because mark-to-market payments on futures introduce an element of reinvestment risk that cannot be fully hedged. However, index futures differ from other financial futures because the arbitrage trade is difficult to do as we will explain briefly below. This results in fairly wide deviations of actual futures prices from theoretical forward prices.

Cash-forward arbitrage relationship: the no-dividend case. According to arbitrage arguments identical to those used in previous sections, the forward price of a stock index whose constituting stocks do not pay intermediate dividends has to be equal to the current level of the index times the financing cost, that is,

Forward index price = Initial level of the index ×
[1+ (financing rate/100)×(days to futures delivery/360)]

If the futures price is higher than the above theoretical price, profits can be made at zero cost by buying the stocks underlying the index, financing this purchase by shorting a money market instrument of the same maturity as the futures contract and shorting futures contracts. If the futures price is lower, the same reasoning applies, but in reverse.

Cash-forward arbitrage relationship: a general approach. In practice, all stock indexes consist of stocks that pay dividends. The holder of a long position in the portfolio of stocks underlying the index will receive the dividends paid by the stocks of the portfolio. Therefore, the arbitrage arguments used above do not apply anymore. The present value per unit of index share of the dividends paid by the stocks in the portfolio between the initial date and the futures expiration date is needed. If this quantity is known, the forward price of the stock index can be computed using the formula:

Forward index price= (Initial level of the index - PV per unit of index share of dividends to be paid) × [1 + (financing rate/100)×(days to futures delivery/360)]

Similarly to the previous case, if the futures price is higher than the above theoretical price, profits can be made at zero cost by buying the stocks underlying the index, financing this purchase by shorting a money market instrument of the same maturity as the futures contract and shorting futures contracts. And, if the futures price is lower, the same reasoning applies, but in reverse.

Caveats. Several caveats need to be considered.

- The computation of the present value per unit of index share of streams of dividends to be paid up to the futures expiration date is involved. It is necessary to project the dividends to be paid on each stock (which also have to be known) in the index up to the futures expiration, cumulate them for each date using the appropriate portfolio weight, convert these daily totals into the same basis as the index, and then discount each element of the resulting series back to the initial date.

- Unlike the case of futures on fixed income securities and currencies, the arbitrage between stocks and stock index futures is not easy. The transactions costs and execution delays in assembling the stocks of index portfolios in order to trade against the corresponding stock index futures are a big obstacle to arbitrage. This means deviations from the above theoretical prices can arise and persist over long periods.

- None of the arguments above can be applied to the geometric averaging indexes (for example the Value Line Index) because geometric averaging precludes duplicating the index with a portfolio of stocks.

- The above arguments cannot be applied to the futures contract on the Nikkei 225, either. The reason being that the underlying of the CME futures contract on the Nikkei 225 is a portfolio measured in yens but treated as if it were in dollars. Since we cannot construct a portfolio of stocks with such a characteristic, we cannot price this futures contracts using arbitrage arguments.

C. Risk management and hedging

Overview. Stock index futures provide a means of adjusting, acquiring, or eliminating exposure to the fluctuations of overall stock market. Stock index futures strategies may be preferable to other means of adjusting and managing equity exposure because of cheaper transaction costs, attractive prices available on the futures contract, ease of adjusting positions (liquidity), or the difficulty of moving funds quickly and on a large scale into and out of particular stocks.

Adjusting equity exposure. Investors and institutions who wish to increase or decrease their position in stocks relative to bonds and cash can do so via stock index futures. For instance, if a portfolio manager wishes to increase the stock portion of a portfolio by 5 percent, this can be done quickly and cheaply by purchasing stock index futures contracts with a market value equal to 5 percent of the market value of their portfolio. The portfolio manager can subsequently acquire the stocks he or she wishes to hold in the portfolio without missing the profits of an increase in the general level of the market. As stocks are purchased, the futures position can be closed out to maintain the desired exposure to stock market moves. A similar problem is faced when a portfolio manager wants to liquidate positions in less liquid securities. During the long process of liquidation, the portfolio is exposed to market movements. This equity risk exposure can be hedged by selling stock index futures, allowing the manager more time to wait for attractive selling opportunities to develop for the individual stocks.

Hedging stock portfolios. The objective of hedging with stock index futures is to reduce or eliminate the sensitivity of an equity portfolio to changes in the value of the underlying index. The sale of stock futures against a stock portfolio creates a hedged position with returns very similar to those of a short-term, fixed-income security. An interesting example of users of stock futures as hedging vehicles are brokers and dealers in equities. These institutions hold positions in stocks for short periods as a result of their trading operations. They can employ futures on stock indexes for hedging their positions when a major market move is occurring in the market, and they are forced to have large amounts of their capital at risk in the process of meeting their customers' orders.

Creating synthetic index fund portfolios. Futures can be used to create portfolios that have cash flows characteristics similar to an index fund portfolio. Managing index fund portfolios involves considerable oversight in terms of maintaining the correct weights as prices change and reinvesting any dividends that are received. Index futures can provide a means of cheaper access to such a portfolio. The commissions associated with stock index futures are only a fraction of those acquiring the stock themselves. The replicating strategy involves purchasing stock index futures with a contract value equal to the desired valued of the index fund. Funds not used for margin purposes are invested in very low-risk, liquid, short-term securities as Treasury bills or eurodollar deposits.

Capitalizing on different tax treatment of futures and equities. Given that stock index futures can be used to create portfolios that have cash flows characteristics similar to an index fund portfolio, the different tax treatments of those returns may make it advantageous for some investors to use equity futures. All profits and losses on stock index futures are effectively treated as long-term capital gains and losses. This means that on an after-tax basis, an investor with a holding period of less than six months would be better off holding stock index futures in a period of market index appreciation and worse off in a period of declining index values.

D. Expressing a market view

Outright trading. As explained in previous sections, futures are a natural instruments to express views on future exchange rate movements. Here, we should mention that stock index futures provide a means to participate in the movements of the equity market as a whole using a high degree of leverage. Since a deposit of less than 10 percent is required to purchase or sell a stock futures contract, one can take on a considerable amount of market risk via index futures and reap the reward of being correct in a forecast of the stock market direction.

Spreads. A wide range of speculative strategies are possible by mixing stock index futures contracts of different maturities and or different underlying indexes.

Capitalizing on stock selectivity. Certain investors may feel that they can profit most by purchasing stocks that are undervalued with respect to company-specific characteristics rather than making a judgement call on the overall stock market. These investors may not wish to be subject to the risk of the overall stock market movements. The strategy that should be employed is to sell stock futures up to reduce or eliminate the market-related component of that portfolio's risk and returns, and leave the returns and risk component associated with the company-specific features of the stocks in the portfolio.

VI. Options on Futures

A. Definition and Pricing

Definition and types of options. The key to options is to understand that holding an option represents a *right* rather than an *obligation*. There are two types of options on futures:

- A *call* option confers upon its holder the right to establish a long (buying) futures position.

- A *put* option confers upon its holder the right to establish a short (selling) futures position.

In either case, the futures position may be established by the option holder on any date up to a pre-determined *expiration date* at a pre-determined price (the *strike price).* The purchaser of the option pays a market-determined price (or *premium)* in order to have the right --but not the obligation-- to establish the corresponding futures position by *exercising* the option at some time in the future. Conversely, the *writer* (or seller) of the option receives the premium when the option is issued and must stand ready to accept the corresponding futures position at any time during the life of the option.

"Moneyness" of options. An option can never be worth less than zero (once contracted and after paying the premium) because its holder always has the option of letting the option expire unexercised. The *intrinsic value* or *moneyness* of an option is the higher of its value if it were to be exercised immediately and zero (its value if it is not worth exercising), whichever is greater. For example, for a call, if the market price of the underlying is above the option's strike price, the option has exercise value and is said to be *in the money.* If the market price of the underlying is below the call option's strike price, the option has no exercise value and is said to be *out of the money.* The same applies, but in reverse, to put options. The option's value will be greater than its intrinsic value because of *time value:* even if the option is not currently in the money, there is always a chance that, given time, it will pay. The premium or *extrinsic value* is therefore the sum of intrinsic value and time value.

Futures positions at option exercise. To summarize, the options on futures, if exercised, yield the following futures positions:

bought call		*if exercised*		long futures
bought put		*by the party*		short futures
sold call	⇒	*long the*	⇒	short futures
sold put		*option, yields*		long futures

Option contract mechanics. As with other exchange-traded futures and options, either writers of options on futures or their holders can close out their options prior to expiration by establishing an offsetting position at the exchange. Options on futures are also subject to margin requirements. Most clearing houses margin option positions, along with futures positions, using the SPAN methodology. As the entire portfolio changes from day to day, so does the margin. Premiums are paid in their entirety when option positions are established.

Underlying instruments. There are options on all the types (though not necessarily on all the specific contracts) of financial futures. Among the most liquid option contracts (and the corresponding exchanges where they are traded) are:

- Short-term interest rates: Eurodollars (at the CME)
- Longer-term interest rates: US Treasury bonds and notes (at the CBOT)
- Currencies: Deutschemarks and Yen (at the CME)
- Stock-indexes: S&P500 (at the CME)

Example: option on eurodollar futures. A *call* option on a eurodollar futures behaves very much like a *floor* on short-term interest rates. If 3-month LIBOR falls below a certain level (corresponding to 100-strike price), the option will be exercised and hence the option holder will have bought a futures position in a low interest rate environment. But if 3-month LIBOR rises above the level given by 100-strike price, the call will not be exercised and the option holder will not establish a futures position. Conversely, a *put* option on eurodollar futures behaves very much like a *cap* on 3-month LIBOR. (Note that, in practice, the premium on eurodollar options is quoted in terms of basis points that are worth $25 each, matching the tick value of the futures contract.) Interest rate caps and floors can be put together with exchange-traded options or else can be traded over-the-counter.

Pricing models. A commonly used pricing model for options on futures is the Black model, which is an extension of the Black-Sholes model originally derived for pricing equity options. The software for the more commonly used pricing models is readily available.

Option value components. The basic components of option pricing relate to the characteristics of the option and of the underlying future:

- the strike price
- the time to maturity
- the underlying futures price, and
- the volatility of the underlying price.

Options experience a gradual fall in value as they approach expiration; this is termed *time decay*. All options gain in value with higher volatility. Option value also increases proportionately with its *moneyness*, which is essentially given by the difference between the (fixed) strike price and the (variable) underlying futures price.

Put/call parity. Any future position can be replicated by combining puts and calls on that future. In particular, a long call option together with a short put option (of the same underlying, strike price and expiration date) behave like a long future.

B. Applications

Overview. The basic applications of options contracts are analogous to those of futures contracts, namely, arbitrage, risk management and market positioning. The mechanics of arbitrage trades are less straight-forward (though not necessarily less frequent or lucrative) than futures arbitrage because of the more complex nature of option arbitrage. We will not discuss them here as we have not introduced any particular option pricing model in sufficient detail.

Use of options on futures versus use of futures. Hedgers and investors might want to use options on futures rather than futures themselves for the following reasons:

- Creating *asymmetric payoffs* on the upside and downside. There is no downside risk to buying an option. If the price goes against you, you let the option expire worthless and pay no more. With a futures position, you must pay the daily settlement variation when the price goes against you. The price you pay for having the security offered by an option is the upfront premium. Conversely, if you are willing to accept the risk of an unlimited downside exposure, you might consider selling an option and collect the premium upfront. Thus, whether futures or options on futures are utilized by traders and corporate treasurers depends on their preferences on the risk/reward structure.

- Hedging or trading on the basis of *market volatility*. Futures are not directly affected by changes in market volatility. Some users, however, might want to hedge market volatility, or actually express views on the basis of market volatility. Only options allow them to isolate the volatility component on the basis of which they can hedge or trade.

- *Contingent contracts.* Options might be suitable if the asset, liability or cash flow being hedged is of a contingent nature. For example, suppose you are negotiating with a Japanese company for electrical parts. The Japanese company will decide at the next board meeting, which takes place in a month, whether to provide parts at the agreed-upon prices. The U.S. corporation will lose its profit margin if the yen appreciates relative to the dollar at the time the Japanese firm agrees to the contract. In this case, it may pay for the U.S. firm to hedge the contingent payable by *buying* options on yen futures.

Hedge ratios. When used as hedge instruments, options on futures need to be used under carefully crafted hedge ratios. The basic construction of the hedge ratio follows the same principle as for futures: the hedge instrument should have the same sensitivity as the hedged asset or liability to movements in the price of the underlying. However, option-based hedges need to be adjusted dynamically through time to keep pace with changes in the options' sensitivity to changes in the price of the underlying (due to changes in time to expiration, the degree of *moneyness* or volatility). With futures, on the other hand, the relationship between the price of the underlying and the price of the future is basically constant and hence futures-based hedges are essentially static.

Hedging example: floating-rate note issuance. In chapter 2 we saw a hedging example where futures were used to fix the interest rate on a floating-rate notes issued by a corporation. Options on futures can be used instead to insure against adverse interest rate moves. For a fixed price (the option premium), and interest rate cap (i.e. long a put on eurodollars) allows the borrower to take advantage of favorable rate moves while limiting the damage done by an rises in rates. As a result, when rates are low, net interest expense is higher in the hedged position because of the option premium paid up-front. But when rates are high, the net interest expense can be substantially lower than it would be with straight floating-rate financing. The level of the option's strike price determines the degree of *insurance* or *protection* bought the borrower.

Spreads. There are many popular spread combinations using options of different strike prices, expiration dates or even underlying futures contracts. They allow the investor or money manager to take advantage, in part, of both buying and selling options. Calls and puts can be combined to produce very specific risk/return tradeoffs. Consider several of the more basic examples:

- *Straddle.* It is constituted by a long (short) position in both a cap and a floor, and can be used to bet that interest rate volatility will rise (fall).

- *Collar*. It is constituted by a short position in an out-of-the-money call (put) and a long position in an out-of-the-money put (call). The long and short option positions can be established so as to make the trade *self-financing*, i.e., requiring no premium up-front. Under a collar, the exposure to the underlying is allowed to vary only between the two strike prices.

- *Corridor*. A put with a low strike price can be sold to held defray the cost of a put with a high strike price. This has the effect of fixing the payoff over the range of prices between the two strike prices. The underlying price is free to vary below the lower strike price and above the higher strike price.

Trading volumes. The volume traded on options on futures is much larger than on equivalent options on the cash instruments. This is due to the fact that futures are leveraged instruments. This makes options on futures easier to hedge dynamically since one does not need to worry about financing of positions in the underlying.

VII. Concluding Remarks

A. Liquidity and market depth

Overview. In derivatives markets, unlike in cash markets, most of the action happens in the future. Because they bind buyer and seller for a pre-specified period of time, users will only feel comfortable using derivatives markets if they are liquid and deep enough to allow investors to rebalance their portfolios in response to new information at low cost. Whether one uses futures to hedge future risks, to take market positions or to exploit market inefficiencies, the reversibility or dynamic adjustment of trades is key.

Market liquidity. A market is *liquid* when traders can buy and sell *without substantially moving the price* against them. Liquidity typically arises when there are individuals or institutions which continuously wish to buy or sell. Liquidity is provided to a large degree by *locals* (individuals trading on their own capital) trading in the pit, or else by major financial institutions trading in automated systems. They supply liquidity by absorbing order flow imbalances; the difference between their buy and sell prices are the effective bid-ask spread. The bid-ask spread can be interpreted to be an indicator of market liquidity as it represents the cost of entering and exiting a given position (other than commission costs). In contrast, dealers are the primary suppliers of liquidity in OTC markets. But in OTC markets, the effective bid-ask and the dealer's commission tend to be lumped together so that direct comparison of bid-ask spreads cannot be used to measure the relative liquidity across markets. Alternatively, one can gage liquidity by looking at trading volumes: just how often do trades occur and how large are they? Here, again, comparison across markets is made difficult by the lack of transparency of OTC markets were trade data is essentially private.

Market depth. Nominal bid-ask spreads and the extent of market liquidity depend on the size of orders. A market is *deep* if traders can buy and sell *in large quantities* without substantially moving the price. Evaluating markets by their depth is a tougher standard than just looking at liquidity. In a sense, it measures how "robust" the observed market liquidity is to large orders. One can get a sense of the depth of exchange-traded futures markets by analyzing trading volumes and *open interest* (the number of open contracts outstanding at any point in time). Again, collecting the equivalent data for OTC markets is much more difficult. A related aspect of interest to futures markets participants is the risk of an unexpected and sudden erosion of liquidity caused by a sudden price movement or new information.

B. Summing up: Importance of futures markets

Summary. Over the last decades, futures have become widely accepted by money managers, financial institutions and corporations and have been successfully integrated into risk management and yield enhancement strategies. We have investigated some of the features of futures contracts, explained some of the basics regarding how they are priced, and given a few applications illustrating how these contracts would be used by risk managers and investors.

Economic importance of futures. Futures, and derivatives generally, allow economic agents to fine tune the structure of their assets and liabilities to better suit their risk preferences and market expectations. They are not *per se* a financing or investment vehicle but rather a tool for transferring price risks associated with fluctuations in asset values. Some may use them to spread risk, others to take on risk on the basis of particular market views.

Futures as a building-block. Futures have been a key instrument in facilitating the modern trend of separating conventional financial products into their basic components. In so doing, they allow not only the reduction or transformation of risk faced by individual investors but also the sheer understanding and measurement of risk. Financial futures (along with options) are best viewed as *building blocks*. Financial management is quickly becoming an exercise in reducing financial structures into their basic elements and then reassembling them into a preferable structure. In the process, derivatives have contributed decisively to the integration of financial markets.

The surge in financial futures. Without resorting to tedious quantification, the astounding growth and importance of derivatives can be illustrated by the fact that the value of exchange-traded eurodollar derivatives (futures and options) is now roughly 13 times the value of the underlying market. Also, the volume of financial futures now dwarfs the volume in traditional agricultural contracts.

Futures' features. While the following are noteworthy advantages that futures have over forwards, it should be noted that our goal is to illustrate how futures can be used effectively as an investment alternative and as a risk transfer mechanism.

- Futures are relatively inexpensive to execute (negotiable commission rates).

- Futures are bought or sold on margin, and as such provide for substantial leverage.

- Prices are determined by a competitive market system (open outcry or electronic bidding).

- All prices and information are available continuously. Participants know all transaction prices and there are no negotiated deals and no multiple phone calls to get price quotes.

- Positions are easy to reverse if the opinion about market conditions and prospects changes. Offsets of longs and shorts prevent a bloating of the balance sheet and tieing up of credit lines that can become a problem with over-the-counter derivatives.

- Audit systems and safeguards enforced by regulatory authoritics, exchanges and futures commission merchants provide a level of integrity for the marketplace.

- Counterparty credit risk of non-performance is negligible.

On the other hand, OTC trading allows more flexibility in establishing contract terms and avoid the need for daily monitoring of mark-to-market positions and margin account.

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